

## FY20 RSM IPR

# Ensemble Riprap and Scour Calculator in HEC-RAS Stanford Gibson (HEC) and David May (CHL)



**BLUF**: The USACE Riprap software is out of date and does not run on some operating systems. We are incorporating updated USACE scour and riprap design tools in the Hydraulic Design editor of HEC-RAS.

### Challenge/Objectives

- Standardize state-of-practice of USACE scour and riprap design.
- Avoid costly failure modes or over-design by automating scour and riprap tools.
- Increase analysis efficiency.
- Compute scour with an ensemble of appropriate equations to bound the range and communicate uncertainty.

### Approach

We are incorporate these methods into HEC-RAS.



Image from David May

# FY20 RSM IPR

## Ensemble Riprap and Scour Calculator in HEC-RAS



**Stanford Gibson (IWR-HEC)**  
**David May (ERDC-CHL)**

We also received guidance and assistance from:

**Chris Haring (ERDC-CHL)**  
**David Biedenharn (ERDC-CHL)**

### **Leveraging/Collaborative Opportunities:**

**The study team worked with MVP on scour and riprap calculations for the American River levee scour project. We worked with the district and ERDC SMEs to formalize the analysis steps and design work flow for the HEC-RAS tools.**

### **HEC Developers and Testers**

Anton Rotter-Sieren  
Jay Pak

### **Stakeholders/Partners**

USACE-SPK  
USACE-MVP  
Maricopa County  
Everyone who sizes riprap



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## Ensemble Riprap and Scour Calculator in HEC-RAS



### Accomplishments/Deliverables

- State-of-Practice Methods Review
- Scour and Riprap Pseudo Code
- Interface Design

### -Application Development (Three –Step Workflow)

1. Size Riprap  
(Identify Appropriate Available Rock)
2. Compute Scour for Launchable Toe
3. Calculate Total Rock Volume

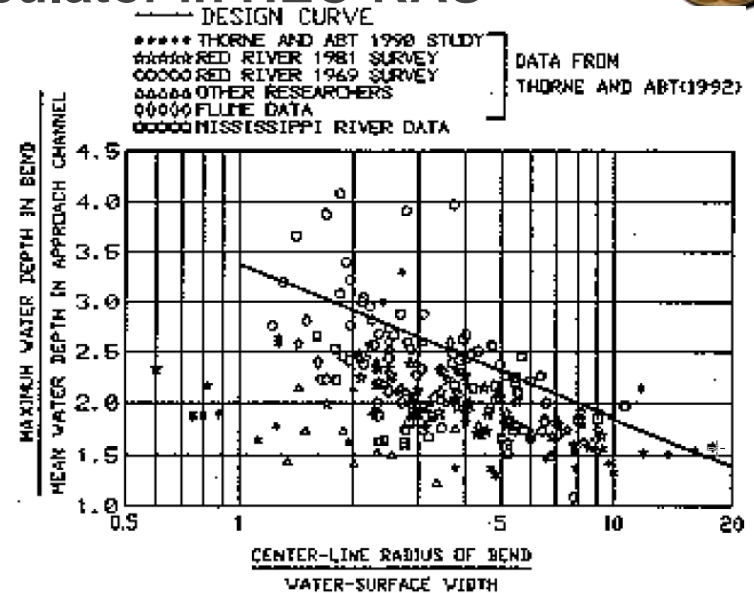


Image from David May

# Scour Calculator - Design

Size Rip Rap (& Thickness)

Compute Scour Depth

Compute Volume

Multiple Cross Section Analysis

Profile Name:

Hydraulics

Hydraulics

Computation XS: \*

Crossing Reach XS:

River

River

Reach  RS

Reach  RS

Hydraulic Data

Upstream Crossing XS (Bend Scour Only)

Design Q (ft<sup>3</sup>/s)

Design Q (ft<sup>3</sup>/s)

Design Depth (ft)

Depth (ft)

Velocity (ft/s)

Hydr Radius (ft)

Top Width (ft)

Top Width (ft)

Energy Slope

Z

Velocity (ft/s)

Hydr Radius (ft)

Z

Energy Slope

Design Depth<sub>Max</sub> (ft)

Z

Depth<sub>Max</sub> (ft)

Manning n-value

Radius of Curvature (ft)  → Degree of Bend

Temperature (°F)   Use Lacey Regime Eqn for Depth

d<sub>50</sub>  d<sub>90</sub>

## Select Methods

- Bend Scour Methods
  - Maynard
  - Zeller
  - Thorne
  - USACE
- General Scour
  - Zeller
  - Neil
  - Lacey
  - USBR Envelope
  - USBR Vel<sub>mean</sub>

## Niell Incised Data **N**

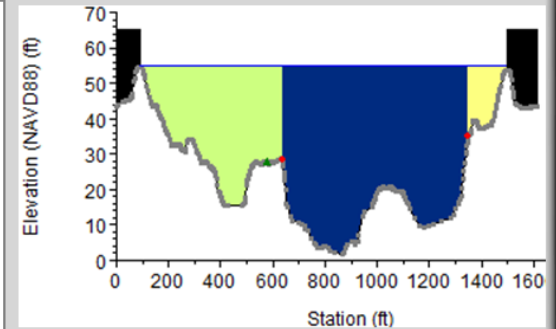
Bankfull Q (cfs)

Bankfull Width (ft)

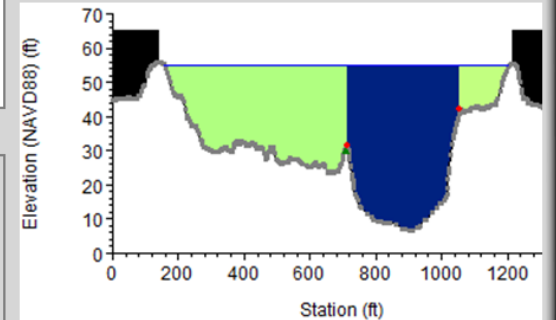
Bankfull Depth(ft)

Neill Exponent

Evaluation Cross Section



Crossing Reference Cross Section



# Scour Calculator - Interface

RipRapWindow
\_ □ ×

Size Rip Rap (& Thickness)
Compute Scour Depth
Compute Volume
Multiple Cross Section Analysis

Profile Name: ▼
 Cross Section
 Coordinates

	River	Reach	RS	Hydraulics
Design XS	<span style="border: 1px solid gray; padding: 2px;">Bald Eagle ▼</span>	<span style="border: 1px solid gray; padding: 2px;">Loc Hav ▼</span>	<span style="border: 1px solid gray; padding: 2px;">106466.0 ▼</span>	<span style="border: 1px solid gray; padding: 2px;">Channel ▼</span>
Crossing XS	<span style="border: 1px solid gray; padding: 2px;">Bald Eagle ▼</span>	<span style="border: 1px solid gray; padding: 2px;">Loc Hav ▼</span>	<span style="border: 1px solid gray; padding: 2px;">118300.5 ▼</span>	<span style="border: 1px solid gray; padding: 2px;">XS ▼</span>

<b>Hydraulic Data</b> <table style="width: 100%; border-collapse: collapse;"> <tr><td>Design Q (ft<sup>3</sup> / s)</td><td><span style="border: 1px solid gray; padding: 2px;">192000</span></td></tr> <tr><td>Design Depth (ft)</td><td><span style="border: 1px solid gray; padding: 2px;">14.8</span></td></tr> <tr><td>Velocity (ft/s)</td><td><span style="border: 1px solid gray; padding: 2px;">2.4</span></td></tr> <tr><td>Top Width (ft)</td><td><span style="border: 1px solid gray; padding: 2px;">1223.5</span></td></tr> <tr><td>Energy Slope</td><td><span style="border: 1px solid gray; padding: 2px;">0.003</span></td></tr> <tr><td>Hydr Radius (ft)</td><td><span style="border: 1px solid gray; padding: 2px;">16.3</span></td></tr> <tr><td>Design Depth Max (ft)</td><td><span style="border: 1px solid gray; padding: 2px;">21.6</span></td></tr> <tr><td>Manning n-value</td><td><span style="border: 1px solid gray; padding: 2px;">0.023</span></td></tr> </table>	Design Q (ft <sup>3</sup> / s)	<span style="border: 1px solid gray; padding: 2px;">192000</span>	Design Depth (ft)	<span style="border: 1px solid gray; padding: 2px;">14.8</span>	Velocity (ft/s)	<span style="border: 1px solid gray; padding: 2px;">2.4</span>	Top Width (ft)	<span style="border: 1px solid gray; padding: 2px;">1223.5</span>	Energy Slope	<span style="border: 1px solid gray; padding: 2px;">0.003</span>	Hydr Radius (ft)	<span style="border: 1px solid gray; padding: 2px;">16.3</span>	Design Depth Max (ft)	<span style="border: 1px solid gray; padding: 2px;">21.6</span>	Manning n-value	<span style="border: 1px solid gray; padding: 2px;">0.023</span>	<b>Upstream Crossing XS</b> <table style="width: 100%; border-collapse: collapse;"> <tr><td>Design Q (ft<sup>3</sup> / s)</td><td><span style="border: 1px solid gray; padding: 2px;">192000</span></td></tr> <tr><td>Depth (ft)</td><td><span style="border: 1px solid gray; padding: 2px;">12.3</span></td></tr> <tr><td>Hydr Radius (ft)</td><td><span style="border: 1px solid gray; padding: 2px;">14.2</span></td></tr> <tr><td>Top Width (ft)</td><td><span style="border: 1px solid gray; padding: 2px;">1367</span></td></tr> <tr><td>Velocity (ft/s)</td><td><span style="border: 1px solid gray; padding: 2px;">5.47</span></td></tr> <tr><td>Energy Slope</td><td><span style="border: 1px solid gray; padding: 2px;">0.00349</span></td></tr> <tr><td>Depth Max (ft)</td><td><span style="border: 1px solid gray; padding: 2px;">8</span></td></tr> </table>	Design Q (ft <sup>3</sup> / s)	<span style="border: 1px solid gray; padding: 2px;">192000</span>	Depth (ft)	<span style="border: 1px solid gray; padding: 2px;">12.3</span>	Hydr Radius (ft)	<span style="border: 1px solid gray; padding: 2px;">14.2</span>	Top Width (ft)	<span style="border: 1px solid gray; padding: 2px;">1367</span>	Velocity (ft/s)	<span style="border: 1px solid gray; padding: 2px;">5.47</span>	Energy Slope	<span style="border: 1px solid gray; padding: 2px;">0.00349</span>	Depth Max (ft)	<span style="border: 1px solid gray; padding: 2px;">8</span>
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<input type="checkbox"/> Bend Scour Methods <ul style="list-style-type: none"> <li><input checked="" type="checkbox"/> Maynard <span style="border: 1px solid gray; padding: 2px;">20.7721</span> ft</li> <li><input checked="" type="checkbox"/> Zeller <span style="border: 1px solid gray; padding: 2px;">2.55173</span> ft</li> <li><input checked="" type="checkbox"/> Thorne <span style="border: 1px solid gray; padding: 2px;">13.2932</span> ft</li> <li><input checked="" type="checkbox"/> USACE <span style="border: 1px solid gray; padding: 2px;">42.6449</span> ft</li> </ul>	<input type="checkbox"/> General Scour <ul style="list-style-type: none"> <li><input checked="" type="checkbox"/> Zeller <span style="border: 1px solid gray; padding: 2px;">6.24043</span> ft</li> <li><input checked="" type="checkbox"/> Neil <span style="border: 1px solid gray; padding: 2px;">15.4931</span> ft</li> <li><input checked="" type="checkbox"/> Lacey <span style="border: 1px solid gray; padding: 2px;">6.81541</span> ft</li> <li><input checked="" type="checkbox"/> USBR Env <span style="border: 1px solid gray; padding: 2px;">8.24391</span> ft</li> <li><input checked="" type="checkbox"/> USBR Vel <span style="border: 1px solid gray; padding: 2px;">7.4</span> ft</li> </ul>
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<b>Radius of Curvature (ft)</b> <span style="border: 1px solid gray; padding: 2px;">1200</span>	<b>Degree of Bend</b> <span style="border: 1px solid gray; padding: 2px;">Moderate ▼</span>
<b>Temperature (°F)</b> <span style="border: 1px solid gray; padding: 2px;">30</span>	<input checked="" type="checkbox"/> Use Lacey Regime Eqn For Depth
<b>d50 (mm)</b> <span style="border: 1px solid gray; padding: 2px;">20</span>	

<b>Niell Incised Data</b> <table style="width: 100%; border-collapse: collapse;"> <tr><td>Bankfull Q (cfs)</td><td><span style="border: 1px solid gray; padding: 2px;">50000</span></td></tr> <tr><td>BankFull Width (ft)</td><td><span style="border: 1px solid gray; padding: 2px;">1000</span></td></tr> <tr><td>Bankfull Depth (ft)</td><td><span style="border: 1px solid gray; padding: 2px;">12</span></td></tr> <tr><td>Neill Exponent</td><td><span style="border: 1px solid gray; padding: 2px;">0.67</span></td></tr> </table>	Bankfull Q (cfs)	<span style="border: 1px solid gray; padding: 2px;">50000</span>	BankFull Width (ft)	<span style="border: 1px solid gray; padding: 2px;">1000</span>	Bankfull Depth (ft)	<span style="border: 1px solid gray; padding: 2px;">12</span>	Neill Exponent	<span style="border: 1px solid gray; padding: 2px;">0.67</span>	
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	<b>Evaluation Point</b>				
	<table style="width: 100%; border-collapse: collapse;"> <tr> <td style="width: 50%;"></td> <td style="width: 50%; text-align: center;"><b>Crossing Reference Coordinates</b></td> </tr> <tr> <td></td> <td style="text-align: center;"> </td> </tr> </table>		<b>Crossing Reference Coordinates</b>		
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# Riprap Calculator - Design

Size Rip Rap (& Thickness)

Compute Scour Depth

Compute Volume

Multiple Cross Section Analysis

Profile Name:  River:  Reach:

Channel Type:  RS:  XS Station:

Rock Type:

Site Alignment:

Add Source Gradations >>>

Input Data

Compute width from bank stations.

Vavg (ft/s)

Depth (ft)

Width (ft)

Radius of Curvature (ft)

Side Slope Angle (deg)

Safety Factor  \*\*

Unit Wt (lb/ft3)  \*\*

Computed Parameters

Vss (ft/s)

Vss/Vavg

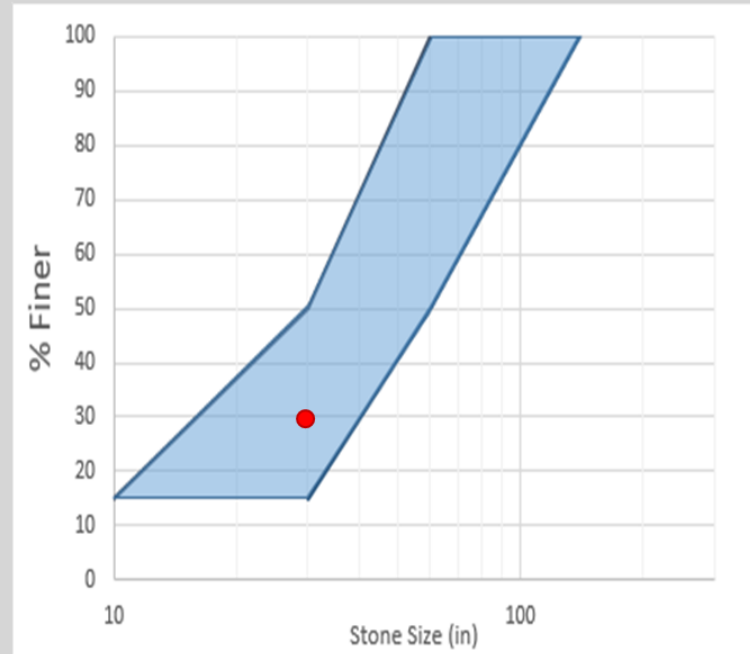
K1

Stability Coef (Cs)

Vert Vel Dist (Cv)

CT  \*\*

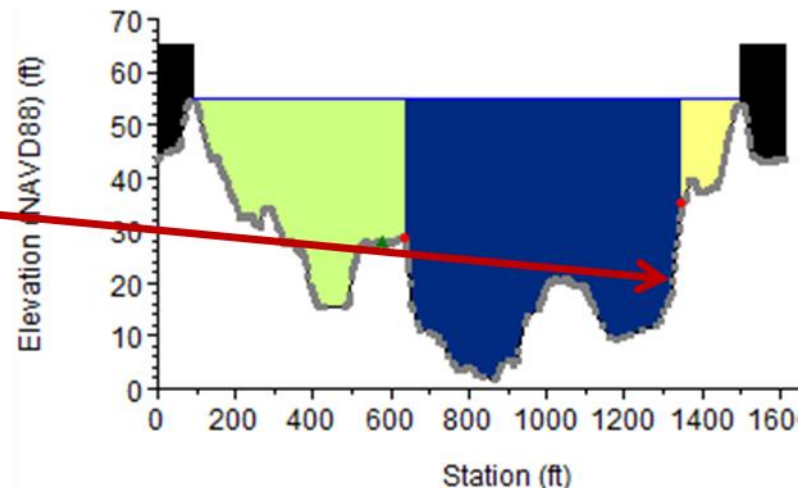
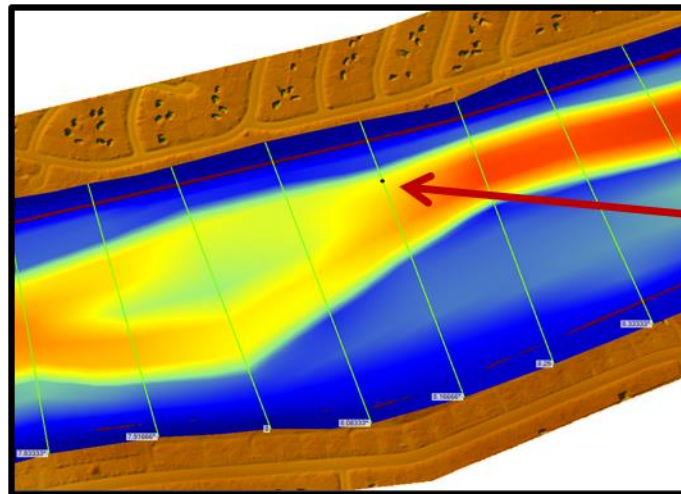
	D30 (mm)	D100 (mm)	Thickness
Avg	<input type="text" value="0.013"/>	<input type="text" value="0.013"/>	<input type="text" value="0.013"/>
SS	<input type="text" value="0.024"/>	<input type="text" value="0.024"/>	<input type="text" value="0.024"/>





### Challenges and Lessons Learned

1. Using 2D (and laterally differentiated 1D) results with classic scour and riprap calculations (based on cross-section averaged velocities) is complicated. It will probably require a research unit to re-derive the equations for local point velocities. For now, we will have to limit the results to 1D simulations or read 2D results along a 1D cut line.



2. HEC developer time during a release cycle can be a little difficult to come by in a release cycle.

## FY20 RSM IPR

# Ensemble Riprap and Scour Calculator in HEC-RAS



- **Standardize state-of-practice of USACE scour and riprap design.**
  - With current code out of date and no longer working on some operating systems, Districts are returning to individual spreadsheets and hand calculations. This tool will standardize best practice.
- **Avoid costly failure modes or over-design by automating scour and riprap tools.**
  - We spend a lot of money dumping rock. We also save a lot of money in damages placing rock. If we place too much rock or its too big, we waste money. If we place too little or it is too small, protected communities incur damages. Getting this right saves money.
- **Increase analysis efficiency.**
  - The rip rap calculations use HEC-RAS output, so it is efficient to build them into the HEC-RAS workflow.
- **Compute scour with an ensemble of appropriate equations to bound the range and communicate uncertainty.**